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CHAPTER SEVEN:
MIX PLACEMENT AND COMPACTION

The procedures for mix placement and compaction are in general specified by the Contractor in the Quality Control Plan for QC/QA HMA (**401**), HMA (**402)** and SMA (**410)** mixtures for the contract.

The paving and compaction equipment on a HMA contract are distributors, pavers, material transfer devices, widening machines, rollers, and hauling units (trucks). Before paving operations may be started, all of the paving equipment is required to be checked for conformance with the Specifications and the Contractor's Quality Control Plan. A pre-paving meeting is a good practice to assure that all of the personnel involved in the paving and compaction operation understand the procedures to be used on the project. Pre-paving meetings should be held prior to beginning paving operations for the project, prior to phase changes in a project, and at the beginning of each construction season for multi-year projects.

WEATHER LIMITATIONS

Hot mix asphalt may be placed only when weather conditions are favorable. Placing the mix on a cold surface or when the air temperature is low causes the mix to cool too quickly. No mixture may be placed on a frozen subgrade. QC/QA HMA courses of less than 138 lb/yd^2 and SMA mixtures are required to be placed when the ambient temperature and the temperature of the surface on which the mix is to be placed is 45° F or above. For Non-QC/QA HMA, minimum temperatures have been established and are summarized as follows:

HMA Courses	Air Temperature	Surface Temperature
Equal to or greater than 220 lb/yd^2	32° F	32° F
Equal to or greater than 110 lb/yd^2, but less than 220 lb/yd^2	45° F	45° F
Less than 110 lb/yd^2	60° F	60° F

HMA courses may be placed at lower temperatures provided the density of the HMA course is controlled by cores as indicated in Section **402.16**.

Paving mixtures may not be laid on wet surfaces or when other conditions are obviously not suitable, even if air and surface temperatures are within the limits. Since rain may be prevalent at the paving site but not at the plant, a means of rapid communication is required to be provided to prevent having several loads of material delivered which may not be used.

ASPHALT MATERIALS

PRIME COATS

Prime coats are used on rubblized concrete pavements to protect the pavement from wet weather. This waterproofing layer prevents excess moisture absorbing into the pavement during rain before paving. The prime coat also allows the pavement to be used for light traffic, binds together any dust on the surface and promotes the bond between the pavement and the HMA overlay. Section **405** includes the requirements for the allowable materials, equipment, preparation of surface, and application rate of asphalt materials and cover aggregate for prime coats. The asphalt material is not allowed to be applied on a wet surface, when the ambient temperature is below 50° F, or when other unsuitable conditions exist, unless approved by the Engineer. The rubblized concrete pavement to be treated is required to be shaped to the required grade and section, free from all ruts, corrugations, or other irregularities, and uniformly compacted and approved.

TACK COATS

Tack coats are used to ensure a bond between an existing HMA mixture and the new HMA mixture. If a good bond is not formed, slippage of the overlay in a longitudinal direction by traffic may occur. Section **406** includes the allowable materials, equipment, and application rate of the asphalt material for tack coats. The existing HMA mixture to be treated is required to be free of foreign materials that may be detrimental to the purpose of the tack coat. Tack coats are not allowed to be applied to a wet surface. The rate of application and areas to be treated are required to be approved prior to application. Excessive tack coat is required to be corrected to obtain an even distribution of the material.

BASE SEALS

Base seals are used on dense graded base mixtures that are immediately below open graded mixtures within the pavement structure. The base seal prevents water carried through the open graded mixture from penetrating the dense graded base course and saturating the subgrade below. Section **415** includes the requirements for base seals.

FOG SEALS

Fog seals are used in conjunction with a joint adhesive to prevent water from penetrating the pavement structure. Because of the difficulty in compacting the asphalt mixture at the longitudinal joint, the fog seal is applied to assist in sealing the material on each side of the joint. If a milled centerline corrugation is applied, the fog seal will seal any cut aggregates that may occur because of the corrugations. Section **412** includes the material and construction requirements for a fog seal.

JOINT ADHESIVE

Joint adhesives are used between adjacent mats to provide a waterproof seal at the joint. The joint adhesive is a hot asphalt material that is applied using a wand applicator on the joint face 1/8 in. thick at the temperature recommended by the manufacturer. The application of the adhesive is made within the same day, but at least 15 minutes prior to construction of the longitudinal joint. **RSP 401-R-581** includes the material and construction requirements for a joint adhesive.

DISTRIBUTOR

A distributor is used to apply the liquid asphalt material used for the prime and tack coats. The distributor consists of an insulated tank mounted on a truck or trailer. A power-driven pump forces the asphalt through a system of spray bars and nozzles onto the construction surface. A burner, usually oil-fired with flues within the tank, is used to heat the asphalt to the proper application temperature. The major units for a typical distributor are indicated in Figure 7-1.

The distributor is required to:

1) Maintain the liquid asphalt at a uniform temperature

2) Apply material at a uniform rate

3) Apply material at variable widths

The distributor is required to be equipped with:

1) Accurate volume measuring gauges or a calibrated tank

2) A thermometer for measuring temperatures

3) A power unit for the pump

4) Full circulating spray bars to prevent material cooling in the spray bars. The spray bars are required to be adjustable vertically.

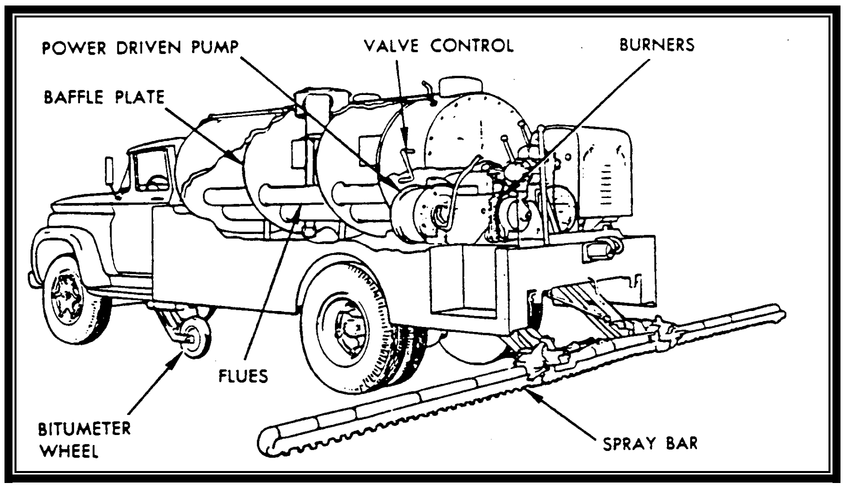

Figure 7-1. Distributor

MIXTURE TRANSPORTATION

HAUL TRUCKS

Haul trucks (Figure 7-2) used to transport the HMA to the paver should be continuously monitored. **402.13** requires HMA in the haul trucks to be protected by tarps from adverse weather conditions or foreign materials. Adverse conditions include, but are limited to, precipitation or temperatures below 45° F. The QCP is required to include the criteria for when waterproof covers are used and designate the person responsible for directing the use of these covers. Also, the procedures for truck unloading and for removing the remaining mixture from the truck bed and apron are required to be included in the QCP. Some daily checks of the trucks that should be made include:

1) Truck beds that are leaking mix because the gates are not tight

2) Foreign material in the mix that would indicate the beds were not clean when loaded. When tarps are used, they should overlap the bed of the trucks enough to prevent rain and foreign material from getting into the mix.

3) The appearance of the mix before the load is dumped

4) Evidence of the excess use of anti-adhesive agent

5) No hydraulic or fuel leaks

Figure 7-2. Haul Truck

Truck Driver Responsibilities

The truck driver responsibilities include assuring that the truck is loaded properly and that there is a consistent delivery of HMA in a homogeneous mass into the paver hopper or transfer unit without causing segregation. Specific responsibilities of the truck driver when using a dump truck include:

1) Load the truck using multiple drop procedures

2) Tarp the load as required to maintain mix temperatures

3) Proceed safely to the paving site and line up properly in front of the paver or transfer unit

4) Back into the paver or transfer unit without bumping

5) Open the tail gate and discharge the mixture in a mass when the paver or transfer unit makes contact with the truck

6) Continue to raise the bed while moving to allow the material to be discharged in a mass

7) Exit immediately when the truck is empty

An alternate procedure for unloading the truck into the paver is possible by raising the bed prior to releasing the tailgate. The procedure is as follows:

1) Back the truck into discharge position stopping short of the paver by 1 to 2 inches

2) Raise the bed slowly until the load shifts to the rear. The paver operator will start the paver forward when he observes the shift of material

3) Release the tail gate when the forward motion is detected and continue to raise the bed as directed

Dump Person Responsibilities

The dump person responsibilities include safely directing the truck into the correct position for discharging the truck into the hopper. Specific responsibilities include the following:

1) Be aware of the safety in and around the paving site, especially overhead obstructions, and warn the paving crew if dangerous situations arise

2) Safely direct the truck into the discharge position without bumping the paver and assuring alignment of the paver and truck to make steering to reference points much easier

3) Watching the hopper to assure that the hopper does not run low or empty. The hopper should be at least 25% full at all times.

MATERIAL TRANSFER VEHICLES

Materials Transfer Vehicles (Figure 7-3) are often used to transfer the mixture from the trucks to the paver and provide the benefits of reduced segregation and increased smoothness. They also may reduce the number of trucks required to deliver the mixture to the paver and improve the balance of the production, paving and compaction operations. If used on a project, **ITM 803** requires that the type and size of the Material Transfer Vehicle and the plan for crossing bridges be included in the Quality Control Plan.

Figure 7-3. Material Transfer Vehicle

The Material Transfer Vehicle operator responsibilities include receiving the HMA from the trucks and transferring the HMA into the hopper.

MIX TEMPERATURE AND APPEARANCE

The quality and temperature of the mix at the paving site should be continually monitored. This is done by visually observing each load and by periodically checking the temperature of the mix before being unloaded.

When the mix arrives at the site, the following items should be checked:

1) The top size of the aggregate is checked to verify that the size is correct for the mix course being placed. The mix designated on the ticket is required to match the type of mix designated for that course.

2) The mix is required to be of similar color throughout the load. Improper mixing at the plant may result in some parts of the mix being lighter in color than others.

3) All aggregates are required to be coated with asphalt. Large coarse aggregate may not be entirely coated because of the rough surface texture.

4) Puddles of asphalt sitting on the mix indicate insufficient mixing. These loads are not acceptable.

5) Blue smoke rising from the mix is an indication that the temperature of the mix is too hot. The temperature of the mix is checked to confirm this observation. A smoky load may also indicate the use of fuel oil as an anti-adhesive in the truck bed.

6) The aggregate particles are required to be distributed throughout the mix. If the coarse aggregates tend to roll out of the truck into the paver at the very beginning or very end of the load, the mix is segregated. Segregation is the most common mix problem.

7) Specifications require the maximum plant discharge temperature to be no more than 315 °F when PG 58-28, PG 64-22, PG 64-28, or PG 70-22 binders are used and not more than 325 °F when PG 70-28 or PG 76-22 binders are used. Mixture temperatures at the paver site should never be higher than these temperature limitations.

To attain the best results, HMA mixtures are required to be placed at the optimum temperature. The temperature of each mixture at the time of spreading is required to not be more than 18° F below the minimum mixing temperatures indicated on the DMF/JMF for non-QC/QA mixtures. Normally, a surface thermometer is sufficient for obtaining an accurate temperature of the mixture.

PLACEMENT OF MIXTURE

PAVERS

HMA mixtures are spread and finished with the use of paver finishers and widening pavers. The HMA paver spreads the mixture in either a uniform layer of a desired thickness or a variable layer to a desired elevation and cross section. Widening pavers are used for widths of less than 8 ft where the normal paver cannot operate.

There are many types of pavers available for placing HMA mixtures. The discussion in this chapter does not include all of the variations available on all pavers. Figure 7-4 illustrates the various components that are common to many pavers.

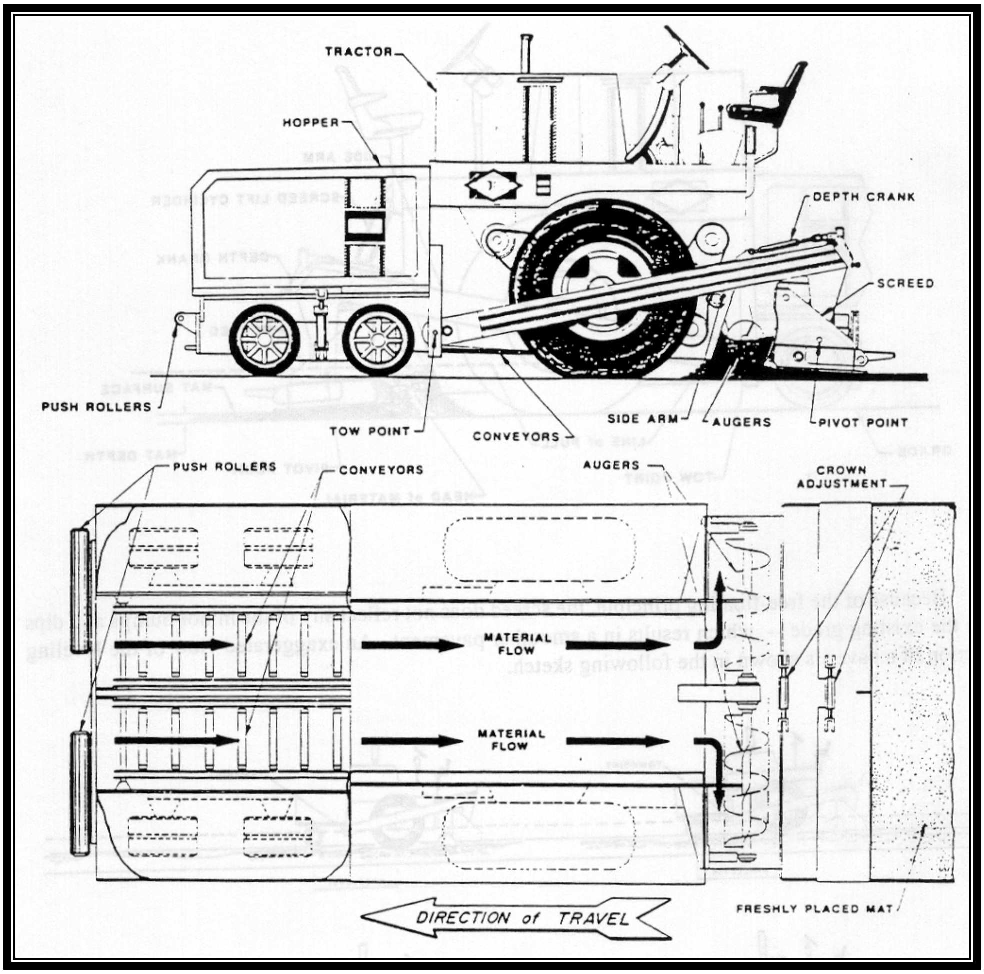

Figure 7-4. HMA Paver

The paver consists essentially of a tractor and a screed. The tractor receives, conveys, and augers the mixture to the screed and propels the screed forward. The tractor may be mounted on either rubber tires or crawlers. In addition to the engine, the tractor unit has a hopper for receiving mix from the haul trucks or Material Transfer Device, conveyors to move the mix through the flow control gates to the augers, flow gates to regulate the flow of mixture to maintain uniform auger speed, and augers to evenly spread the mix in front of the screed. If haul trucks are used, rollers are mounted on the front of the tractor to push the trucks during the dumping process. The rollers turn freely so the trucks have little effect on paver operation. The screed conducts the actual placing of HMA to the desired width and thickness or elevation as indicated in Figure 7-5. The screed is towed by the tractor and is free to float up or down until the bottom of the screed is parallel with the grade over which the screed is traveling.

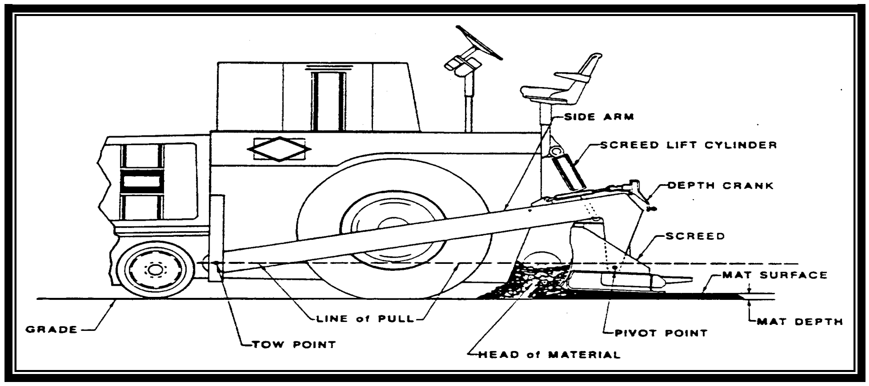

Figure 7-5. Paver Components

Because of the free-floating principle, the screed does not reflect any of the minor bumps and dips in the existing grade which results in a smoother pavement. The leveling action of a paver is indicated in Figure 7-6.

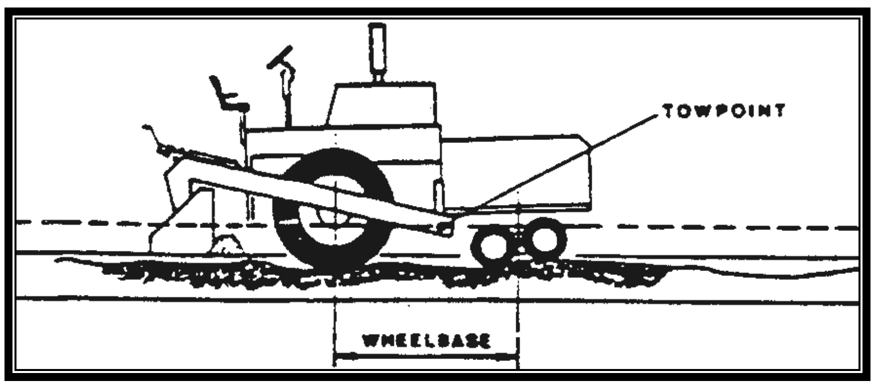

Figure 7-6. Free-Floating Screed

The relationship between the vertical movement of the screed tow point and the elevation of the screed is illustrated in Figure 7-7. There is commonly an 8 to 1 ratio between the tow point and the elevation; therefore, a 1 in. vertical movement of the tow point results in only a 1/8 in. vertical corrective movement of the screed. Before the 1/8 in. movement is made, the paver moves five times the length of the screed side arm. This relationship is the key to the paver's ability to lay smooth pavements.

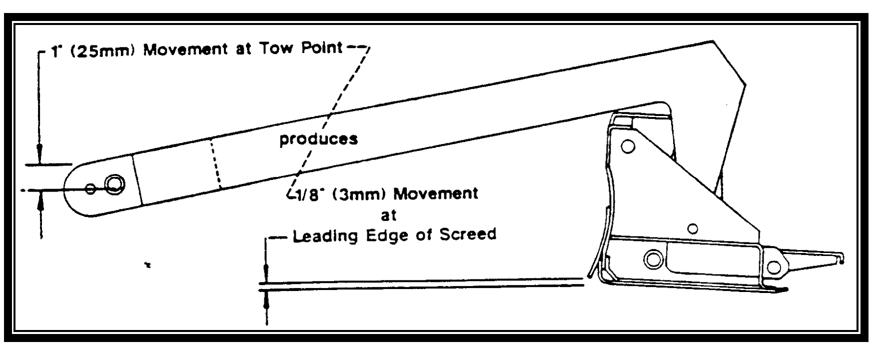

Figure 7-7. Screed Tow Point and Elevation

Section **409** requires that a paver (Figure 7-8):

1) Be a self-contained power propelled unit

2) Be equipped with an activated (vibratory) screed or strike-off assembly capable of being heated for the full length, including extensions

3) Be capable of spreading and finishing mix in lane widths indicated on the typical sections for the contract

4) Be equipped with automatic grade and slope controls if the width of the roadway or shoulder to be paved is 8 ft or wider. The operator's control panel is required to have gauges that indicate compliance with the established grade and slope.

5) Have a grade leveler (commonly called a ski or mat reference) for attachment to the paver to activate the automatic grade control

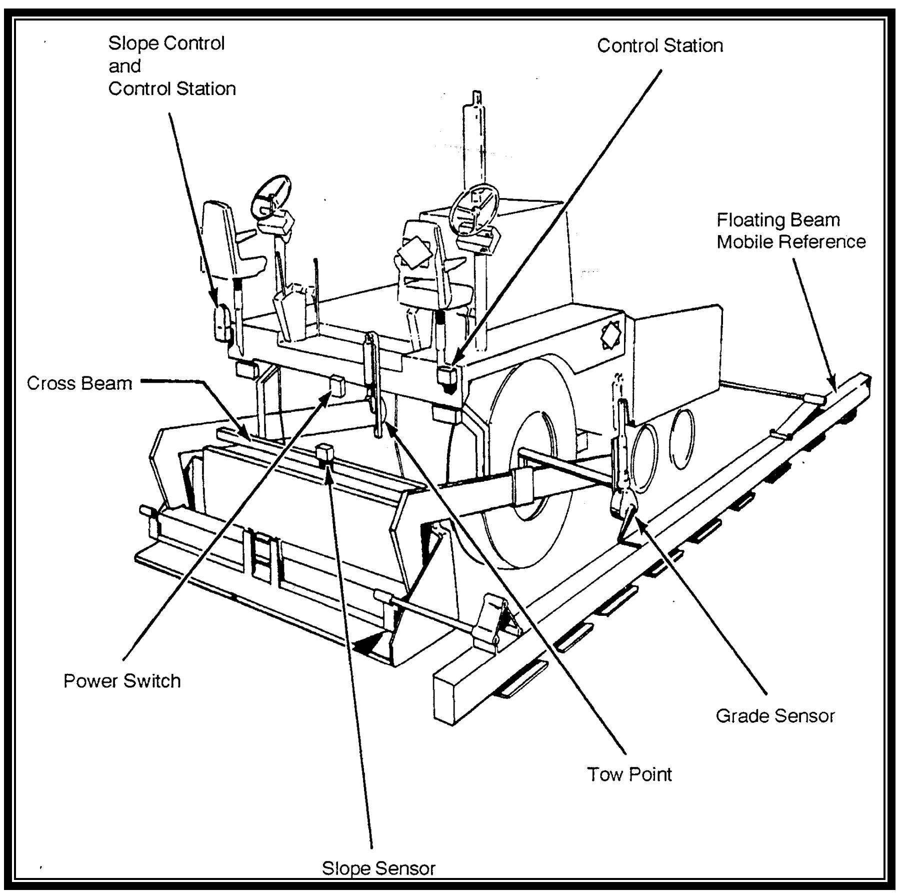

Figure 7-8. Paver Screed Controls

The automatic screed controls may be set for manual, semiautomatic, or automatic operation on most pavers. Automatic screed controls typically have the following main components:

1) Infrared Sonic Sensors

2) Non-Contact Sensors

3) Control station

4) Slope control

5) Motors and hydraulic cylinders to change the screed tilt

The grade sensor rides on a stringline, a ski, or a joint matcher to detect changes in elevation and transmit the information electronically to the controls. The electronic controls may be checked by varying the position of the grade sensor and observing if the screed controls react to make the correct adjustment. When the ski is used, the grade sensor is required to always ride on the center of the ski so that all elevation changes are averaged.

Use of the automatic controls further enhances the paver's capability to produce a smooth pavement surface regardless of irregularities in the surface being paved. Crown or superelevation slope is controlled by the slope sensor or pendulum set for the desired slope. Once the screed is set for the desired mat thickness and slope, the automatic controls activate the motors or cylinders to change the screed tilt to automatically compensate for road surface irregularities. Automatic slope and grade controls are required to be used as outlined in the QCP.

PAVER OPERATION

The operation of the paver is different for the various types of equipment used in the HMA Industry. The information provided in this section may or may not apply to all pavers and is intended to provide information on the general operations of a paver.

Controlling the vertical position of the free-floating screed, with respect to the grade surface over which the paver is moving, is the primary concern in producing high quality paving.

Several factors, such as the paving speed, head of material, mix consistency, pre-compaction, and screed angle of attack influence the vertical position of the screed. If any one of these factors is varied during the paving operation, the variation causes a change in the mat depth, density, and/or texture.

The three primary variable factors which influence the vertical position of the free-floating screed (Figure 7-9) are:

1) Factor F-1 -- Angle of Attack

2) Factor F-2 -- Head of Material

3) Factor F-3 -- Paving Speed

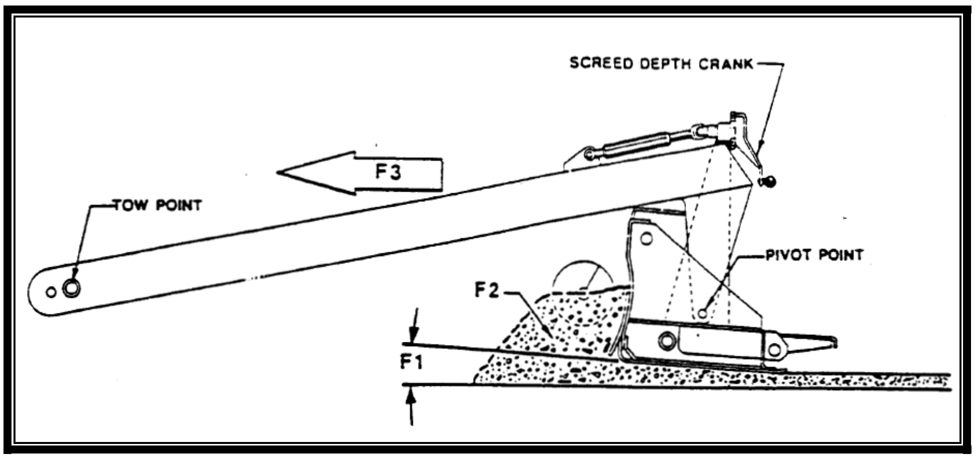

Figure 7-9. Free Floating Screed

The angle of attack is the angle that exists between the bottom surface of the screed and the grade surface over which the paver is moving. Paving over a flat, level surface with all variables held constant produces a mat of constant profile. If the screed or tow points are vertically displaced, a change in the angle of attack occurs. The screed moves to restore the original angle as illustrated in Figure 7-10. The restoration action of the screed is referred to as self-leveling.

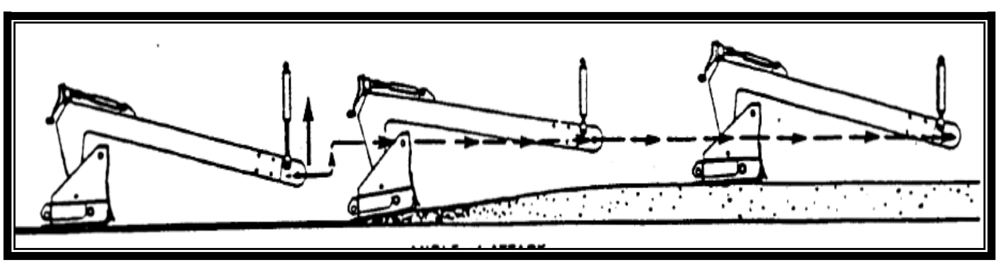

Figure 7-10. Angle of Attack

When the angle of attack is increased, more material is allowed to pass under the screed causing the screed to rise until the screed is again moving in a plane essentially parallel with the grade surface.

Decreasing the angle reduces the amount of material allowed to pass beneath the screed, causing the screed to drop until the screed is again parallel to the grade.

The angle of attack is controlled by either manual screed depth cranks or automatic level controls. One full turn of the depth crank raises or lowers the screed approximately 1/4 in.

Adjustments are made in small increments to produce a smooth riding pavement. The change in depth begins immediately after adjusting the crank; however, the paver is required to move approximately 5 times the length of the screed side arm before the full change in thickness is completed. Once the paver is adjusted for the correct mat thickness**,** very little adjustment of the depth cranks is required.

The head of material is the volume of paving material directly in front of and along the entire length of the screed. The volume and consistency of the head of material are primary factors in the amount of mix that flows under the screed that affect the mat density, texture, and profile. The volume in front of the screed determines the amount of pressure or resistance to forward travel exerted on the screed.

The volume of material in front of the screed is maintained at a near constant level from the center to almost covering the auger shaft along the entire length of the screed (Figure 7-11). Modern pavers have automatic controls to maintain the correct level.

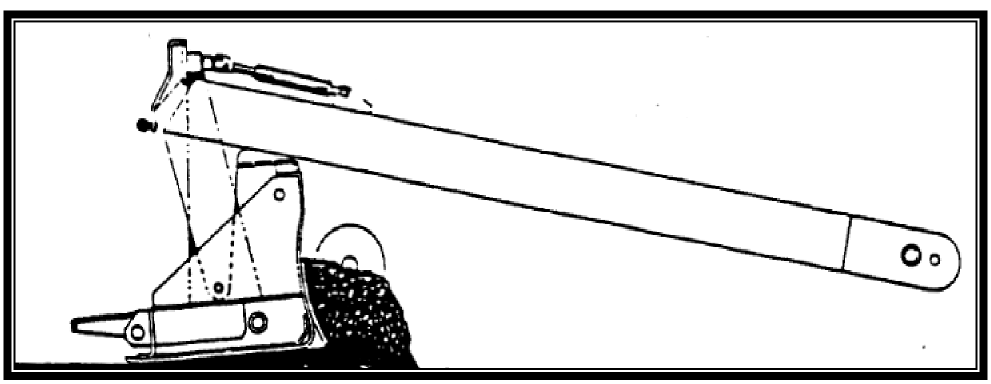

Figure 7-11. Correct Head of Material on Screed

If the head of material is too high (Figure 7-12), the resistance to forward travel is increased. The screed rises and may cause ripples, auger shadows, long waves, increased depth, or a less dense mat.

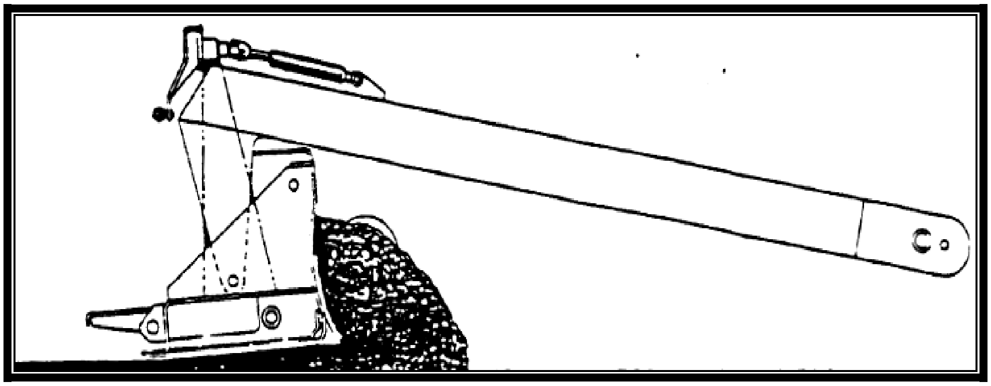

Figure 7-12. Head of Material Too High on Screed

If the head is too low (Figure 7-13), the resistance to forward travel is decreased and the screed gradually falls, resulting in a thin mat and possible voids in the mat.

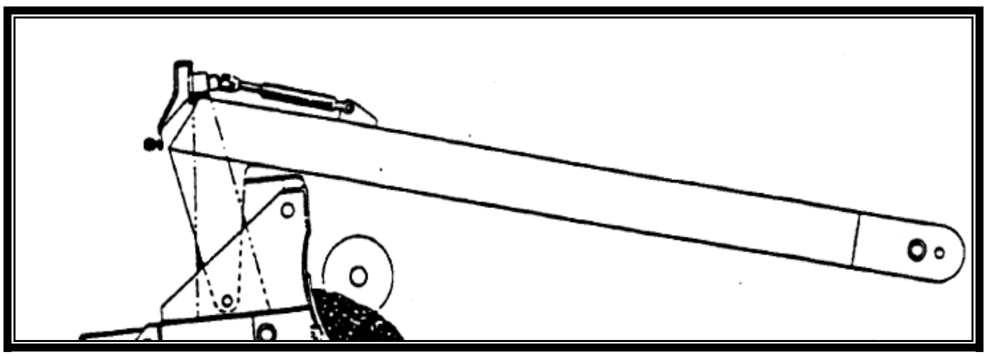

Figure 7-13. Head of Material Too Low on Screed

A fluctuating head of material results in a combination of the mat deficiencies described above plus alternating changes in the mat texture and depth.

The speed of the paving operation is determined by the rate of material delivery to the paver. The optimum speed results in the paver being in continuous operation, using the mixture as the material is delivered, and never having trucks stack up waiting to unload. Continuous, uninterrupted forward travel at a constant speed, with other variables held constant, produces a smooth riding surface. While absolute compliance with this goal is usually not possible, fewer interruptions or changes in paving speed provide a smoother finished surface. The paving speed is required to be adjusted to give a uniform texture and coordinate with plant production.

The paving speed to match the plant production may be computed for any planned quantity. The paving speed and plant production are required to match and be outlined in the Quality Control Plan.

Pavers may not operate at speeds in excess of 50 ft per minute for mixes that are not density controlled by cores. Paver speeds in excess of this speed often result in non-uniform surfaces.

Whenever the absence of loaded trucks necessitates a pause, the paver is stopped with a substantial quantity of mix ahead of the screed. Operating the paver until the mix is too low ahead of the screed results in a dip in the pavement.

In addition to the three major factors discussed, other improper operating procedures which may affect the riding quality of the pavement are:

1) Truck bumping the paver -- this practice is the most common cause of transverse marks and ridges in the finished mat. Drivers are required to stop their trucks ahead of the paver and let the paver operator pick up the truck as the paver travels forward.

2) Truck driver holding brakes -- this practice reduces the paving speed causing an increase in mat depth and may cause the paver wheels to slip or break traction. This problem causes a non-uniform edge line of the mat and a bump in the mat.

3) Paver engine in poor operating condition -- an improperly functioning engine may cause power and speed surges resulting in ripples, waves, or auger shadows in the mat.

4) Unequal or over inflation of paver tires -- this may cause the drive wheel to slip or break traction resulting in a rough, uneven mat.

5) Loose or unevenly tensioned traction drive chains -- this may cause power or speed surges resulting in ripples, waves, or auger shadows in the mat.

Automatic grade and slope controls are required to be outlined in the QCP for mixtures produced in accordance with Section **401.** Section **402** indicates that automatic slope and grade controls are required except when placing mixtures on roadway approaches which are less than 200 ft (60 m) in length or on miscellaneous work. The use of automatic controls on other courses where the use is impractical due to project conditions may be waived by the Engineer.

START-UP

Three types of start-ups are used in hot mix asphalt paving:

1) Full depth

2) Continuing an existing lay

3) Feathering

A full depth start-up is used where paving is started at an intermediate point in the contract. Before starting, the screed is required to be elevated from the grade by the thickness of the mat plus an allowance for the compaction to be achieved by the rolling. Wooden blocks of the required thickness are placed under each end of the screed.

When continuing from a previously laid mat, the tapered material is removed back to the full-depth section and the joint lightly tacked. Strips of lath thick enough to allow for compaction are placed under the ends of the screed as illustrated in Figure 7-14. The front of the screed should never be placed beyond the joint.

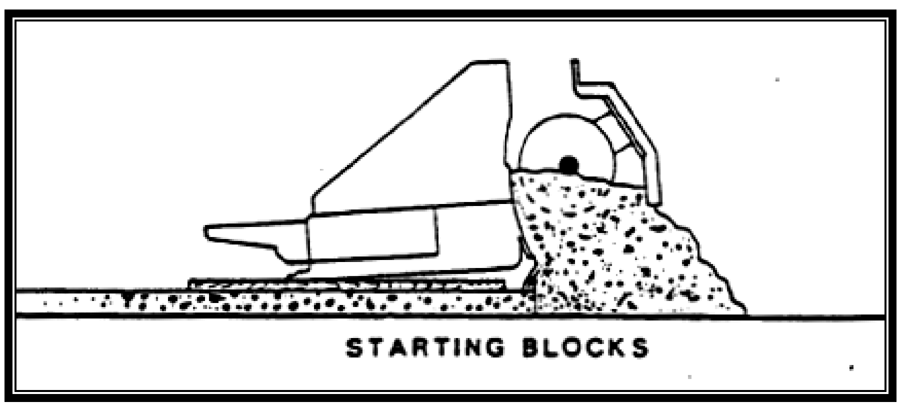

Figure 7-14. Continuing on Existing Lay

When building a start-up feather joint, the screed is set directly on the existing pavement at an angle to gradually taper up to the full depth. The feathering is required to be long enough to provide a smooth transition to the driving surface. Temporary transverse joints, if constructed under traffic, are also feathered.

Paving exceptions are indicated on the plans. Bridges, except for earth-filled arches, are usually an exception from paving. Adding HMA pavement over a concrete bridge deck would cause deterioration to the deck. There may be exceptions when paving under a bridge if the added pavement would reduce the overhead clearance to an unacceptable height. Vertical clearance requirements are designated in **105.08(b)**.

With any start-up, the screed is required to be hot before any mix is processed through the paver. Screed heaters are provided on all pavers to preheat the screed. Once the screed is hot, the heaters may be turned off because the heated mixture keeps the screed hot. Screed extensions bolted on to the paver to attain the required width are also required to be heated. The heating device on the main screed does not provide heat to these extensions.

The front of the screed is required to be set slightly higher than the rear of the screed to provide what is commonly referred to as the "angle of attack". This angle allows the screed to climb enough to equal the amount of compaction that the screed exerts on the mix. Thickness checks are made frequently during the start-up to ensure that the screed is set correctly to produce the desired thickness.

ALIGNMENT

The alignment of the edge of the pavement is critical to the appearance of the highway. When overlaying an existing pavement with a uniform edge, the paver operator may use the edge as a guide for laying the new pavement. When the edge is irregular or the lay is on a new base, an off-set string line to guide the paver is recommended. The requirement for good alignment is discussed with the Contractor before starting the paving operation. Neat lines are a requirement for a good quality pavement.

Another cause of poor alignment is overloading the propulsion capabilities of the paver. On steep grades, the haul truck may be required to dump only a portion of the load and pull ahead to take the additional dead load off the paver. This may also be necessary on fresh tack where the paver is not maintaining traction. Fishtailing of the paver is usually caused by overloading, slipping of the crawlers or drive wheels, or steering clutches in poor condition.

The pointer mounted on the paver is recommended to be rigid rather than a pendulum type because the rigid type permits more control in following the string line or pavement edge.

GRADE AND SLOPE CONTROL

The paver may be equipped with an automatic grade and slope device. The automatic grade device controls the screed to adjust the thickness of the mat as the mix is placed to meet the desired grade. The automatic grade device may be guided with a string line, a grade leveler, or a joint marker, depending on the conditions of the existing pavement.

The screed may also be controlled by turning the depth crank. Once the paver is adjusted to the automatic grade device, the depth cranks are not used. One exception would be if the automatic grade device quit working. Manual controls may be used if this occurs to place the material in transit, however, stopping the operation until repairs can be made is recommended.

The slope meter is used to pre-set the paver to produce the specified cross slopes for crown and superelevation. The screed is hinged in the middle to permit crown adjustment at both the leading and trailing edges of the screed. The leading edge is required to always have slightly more crown than the trailing edge to provide a smooth flow of material under the screed. Too much crown produces an open texture along the edges of the mat. Too little crown results in an open texture in the center.

TRANSVERSE JOINTS

A transverse joint, commonly called a day joint, is normally required at the end of each day's paving to provide a smooth transitional ramp for traffic. One procedure to construct a day joint is indicated in the series of drawings in Figure 7-15; however, there are other acceptable procedures for this joint. The procedure for the construction of the transverse joint is required to be included in the QCP for the project.

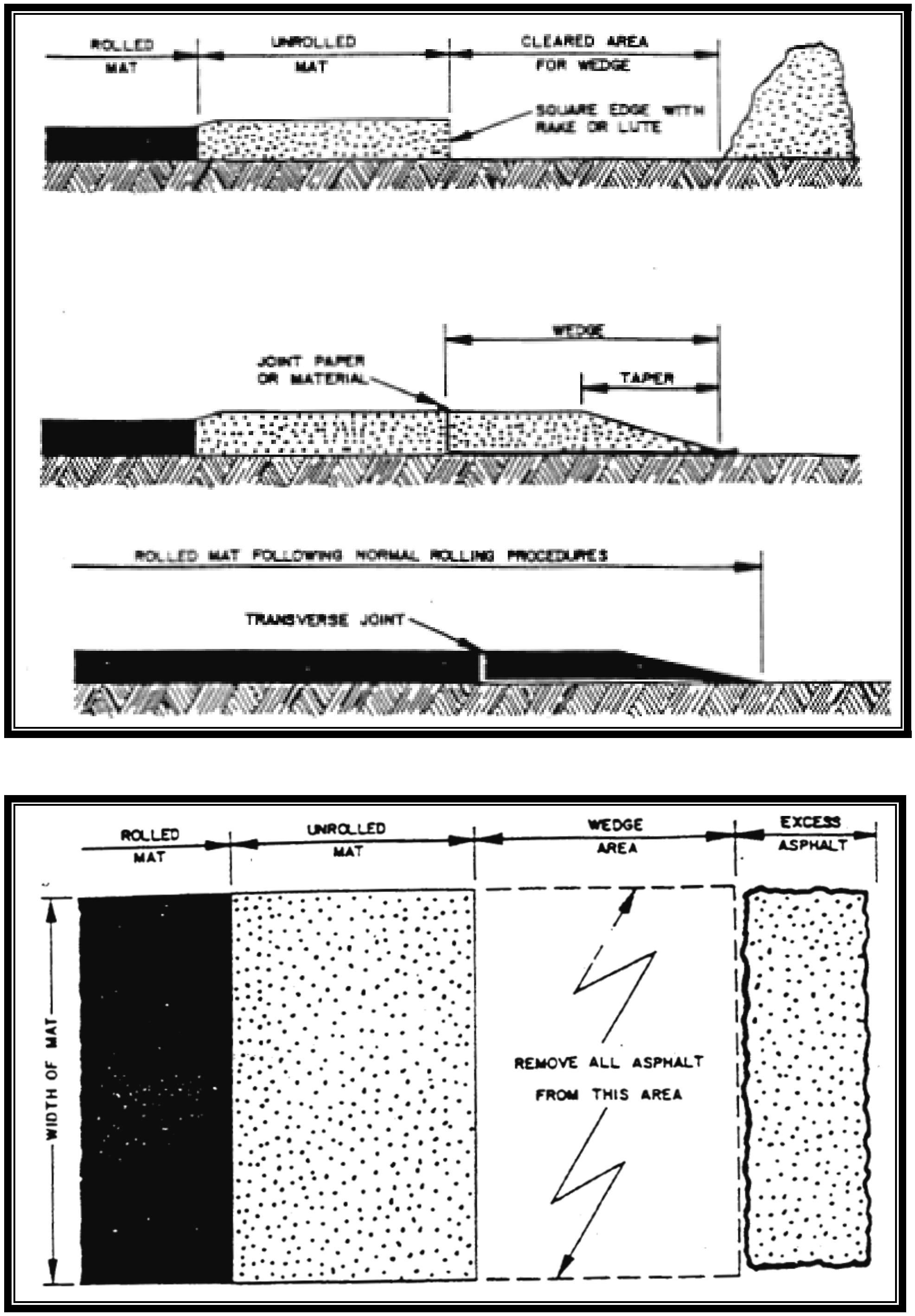

Figure 7-15. Construction of a Day Joint

The last few feet of the mat is left unrolled, the mix is cleared away from the wedge area, joint paper is laid on the existing surface and up the vertical face of the joint, the mix is shoveled over the paper to form the wedge, and the mat is rolled. The Contractor is not allowed to completely empty the paver hopper to make the day joint since some of the mix still in the hopper is too cold. When paving is resumed, the wedge and paper are removed to provide an exposed mat that is full-depth and at the proper grade for continuing the lay. The screed is blocked up with wooden strips as previously described. The paver is positioned with the front of the pre-heated screed over the joint line. After the hot mixture is conveyed into place, sufficient time to re-heat the joint is allowed before moving the paver forward. The paver is advanced enough to allow the workmen to conduct the necessary handwork. The straightedge is required to be used to check the joint to ensure the proper grade before allowing the roller on the surface. Once the joint has been rolled, the joint is rechecked with the straightedge. If any corrections are required there is sufficient heat remaining in the mix to make a smooth joint.

LONGITUDINAL JOINTS

Longitudinal joints are made when joining adjacent lays to make the specified width of pavement. The paver screed does not overlap the previous lay and is carried slightly higher to allow for compaction of the new lay to match the previous lay. The raker uses a lute to remove the excess material from the previous lay into the new lay to obtain a tight, smooth joint and to prevent the rollers from compacting this material into the cold mat. The paver attempts to place the material in such a way that no luting is necessary.

Joint Adhesive

Longitudinal joint performance has been a problem with HMA pavements because of the difficulty of obtaining a tight joint that will resist the penetration of water into the pavement. This water will eventually cause stripping of the underlying layers and deterioration of the joint. A joint adhesive material placed on the joint (Figure 7-16) would reduce the water penetration into the joint and improve the joint performance.

When joint adhesive materials are required by **RSP 401-R-581**, the material is applied to longitudinal joints constructed in the top course of dense graded intermediate mixtures and all surface mixture courses. This includes joints within the traveled way as well as between the traveled way and an auxiliary lane, the traveled way and a paved shoulder, and an auxiliary lane and a paved shoulder.

Figure 7-16. Joint Adhesive

Safety Edge

A safety edge (Figure 7-17) is a wedge of asphalt mixture placed at the edge of the pavement that results in a 30 - 35° angle of mixture. The purpose of the safety edge is to provide a means for a vehicle to leave or access the edge of pavement and therefore reduce roadway departure accidents. The devices approved for constructing the safety edge are listed in Section **409.03 (c)**.

Figure 7-17. Safety Edge

WIDENING MACHINES

Widening machines (Figure 7-18) are used when the width to be laid is too narrow or inaccessible for the regular paver. The inside 4 ft wide shoulder of a dual-lane highway is one example of when HMA may be placed separately using a widening machine.

Widening machines are required to be self-propelled and capable of placing material at variable widths. Vibrating or heated screeds and automatic grade and slope controls are not required for these machines; however, automatic grade controls for matching joints are available on some models. The use of widening pavers is not allowed on widths of 8 ft or more.

Figure 7-18. Widening Machine

Widening machines are equipped with hoppers for receiving the mix from the haul units, conveyors to carry the mix to either side of the machines, and adjustable strike-offs on each side of the machine to allow placing on either side. The strike-off may be adjusted vertically up to 12 in. below or above the grade, depending on the make and model, to allow placing material in lifts.

The strike-off blade does not have the compactive capability of the screed on a regular paver. Consequently, the surface texture is likely to be more open.

The proper adjustment of the strike-off blade is the key to obtaining a good pavement with a widening machine. The settings for the [paver] machine are checked before the paving operation is started. After paving a short distance, the mat is required to be checked for the following:

1) Proper width – if correction is necessary, the width is adjusted by expanding or contracting the strike-off. The outer edge plate may also need to be readjusted parallel with the road edge.

2) Proper elevation – adjusted by raising or lowering the inner strike-offs.

3) Proper slope – adjusted with the outer strike-off support. The sliding outer edger plate, may also require readjustment.

4) Inner edger plate – positioned to prevent paving material from piling up on the existing pavement. The inner edger plate is adjusted to be parallel to the pavement surface set in the lowest position.

5) Flow of material - the flow of material in front of and under the strike-off is watched. Adjustment from the vertical positions may be required.

If the top of the strike-off is tilted back (Figure 7-19), the plate rolls material up. Excessive backward tilt forces the strike-off to pull down into the material.

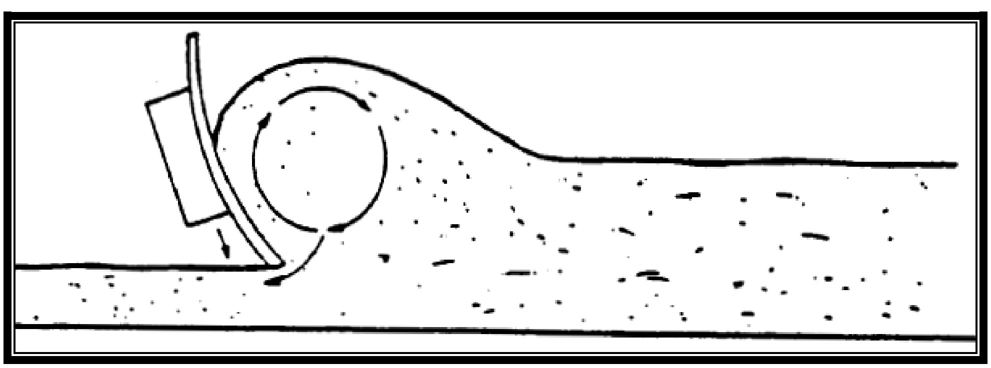

Figure 7-19. Strike-Off Plate Tilted Back

Tilting the top of the strike off plate forward (Figure 7-20) causes the strike-off to roll the material down. Excessive forward tilt forces the strike-off to ride up over the material.

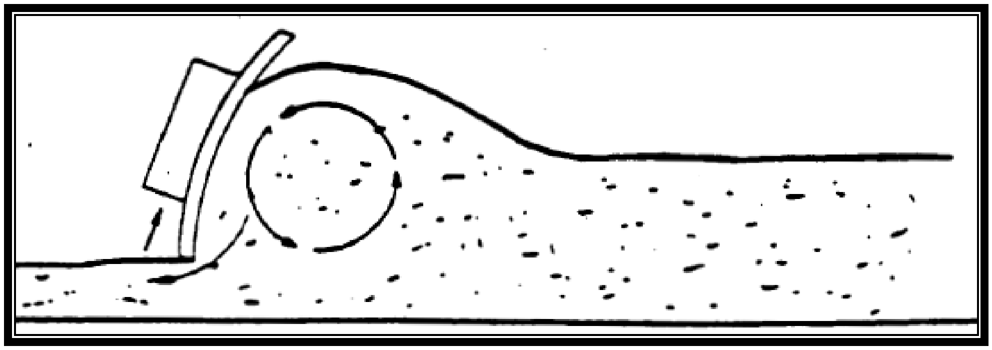

Figure 7-20. Strike-Off Plate Tilted Forward

CARE AND CLEANING OF PAVERS

Pavers are required to be checked for oil and fuel leaks because petroleum products damage the mix. Fuel oil, kerosene, or solvents are not allowed to be transported in open containers on any equipment. Cleaning of equipment and small tools also is not allowed on the pavement or shoulder areas.

The paver hopper, conveyors, augers, and screeds are required to be cleaned at the end of each day. Any hardened mix is removed so the mix is not contaminated when the paving is resumed.

Caution is used at paver cleanout sites because excessive fuel oil saturating the ground may lead to pollution problems. The Contractor is required to clean the areas where the paver is maintained.

PAVING CREW RESPONSIBILITIES

Paver Operators

The paver operator responsibilities include safely operating the paver and using the paver best practices to produce the highest quality pavement possible. Specific responsibilities include:

1) Selecting the paving speed that balances delivery, paver capacity and the compaction process, and paving with few if any extended stops

2) Working with the screed operator in establishing and maintaining the head of material within a plus or minus one-inch tolerance

3) Steering the paver and holding the paver to a pre-determined reference

4) Directing the truck driver to raise the bed and exit when empty

5) Utilizing rapid but smooth starting and stopping operations to help prevent end-of-load roughness

6) Observing the HMA being discharged into the paver hopper or insert for changes in the characteristics of the mixture

7) Monitoring the paver for unusual noise or vibration

8) Working with the dump person to make sure the truck does not bump the paver or that the hopper runs low on material

Screed Operator

The screed operator responsibilities include understanding the basic principles of paving with a free-floating screed and knowing the screed design, operation, and adjustments. An awareness of HMA mix design characteristics and what may change if the mixture varies throughout the day is valuable. Specific responsibilities include:

1) Setting up the screed and paving reference to match the specification requirements for width, crown, slope, and depth

2) Heating the screed properly

3) Working closely with the paver operator in establishing and maintaining the head of material within a plus or minus one-inch tolerance

4) Operating the grade and slope system, utilizing the designated references, and occasionally checking that the mat being laid is being held to the established references

5) Making screed adjustments to produce a consistent textured mat

6) Following the best practices for making sound longitudinal and transverse joints

Lute Person

The lute person (Figure 7-21) responsibilities include assuring that any mat deficiencies are corrected prior to compaction. Specific responsibilities include:

1) Hand working any area of the mat which cannot be placed by the paver

2) Repairing all pavement imperfections

3) Preparing transverse and longitudinal joints for compaction

4) Preparing end-of-pass wedges or tapers for compaction

5) Assisting in cleaning the paver at the end of the shift

6) Assuring the quality of the finished project and communicating problems to the responsible person when they arise

Figure 7-21. Luting Transverse Joint

COMPACTION

ROLLERS

Six types of rollers are used for compacting HMA: two-axle tandem, three-wheeled, pneumatic tire, vibratory, oscillatory, and trench rollers. All of the rollers have steel wheels, except for the pneumatic-tire roller which has rubber wheels.

All rollers are required to have proper sprinkling systems to wet the drums or tires to prevent the mix from sticking. Scrapers are usually required on steel-wheel rollers. Rollers are required to be equipped with drip pans to prevent oil, grease, or fuel from dropping onto the roadway. Clutches are required to function smoothly. A roller that jerks when starting, stopping, or reversing causes a rough surface.

QC/QA mixtures in accordance with **401** and SMA mixtures in accordance with **410** are compacted with rollers determined by the Contractor. HMA mixtures are required to be compacted by the rollers designated in **402.15**.

Tandem Roller

A tandem steel-wheel roller (Figure 7-22) is required by Section **409.03(d)1** to weigh at least 10 tons.

Figure 7-22. Tandem Roller

Three Wheel Roller

The three wheel roller (Figure 7-23) is required by Section **409.03(d) 2** to have a compression or drive rolls that produce a bearing of at least 300 pounds per linear inch of roll width. This bearing weight is computed by dividing the weight of the drive axle by the combined width of the two rolls. A tandem roller, which has a drive wheel bearing of no less than 300 pounds per linear inch may be used in lieu of the three wheel roller.

Figure 7-23. Three Wheel Roller

Pneumatic Tire Roller

A pneumatic tire roller (Figure 7-24) is required by Section **409.03(d) 3** to:

1) Be self propelled

2) Have a minimum width of 5 ft 6 in.

3) Be equipped with compaction tires, with a minimum size of 7:50 by 15

4) Be capable of exerting a uniform, average contact pressure from 50 to 90 pounds per square inch over the surface by adjusting ballast and tire pressure

5) Have wheels on at least one axle that are fully oscillating vertically and so mounted so as to prevent scuffing of the surface during rolling or turning

Figure 7-24. Pneumatic Tire Roller

The tires on a pneumatic tire roller are typically arranged so the gaps between the tires on one axle are covered by the tires of the other as shown in Figure 7-25.

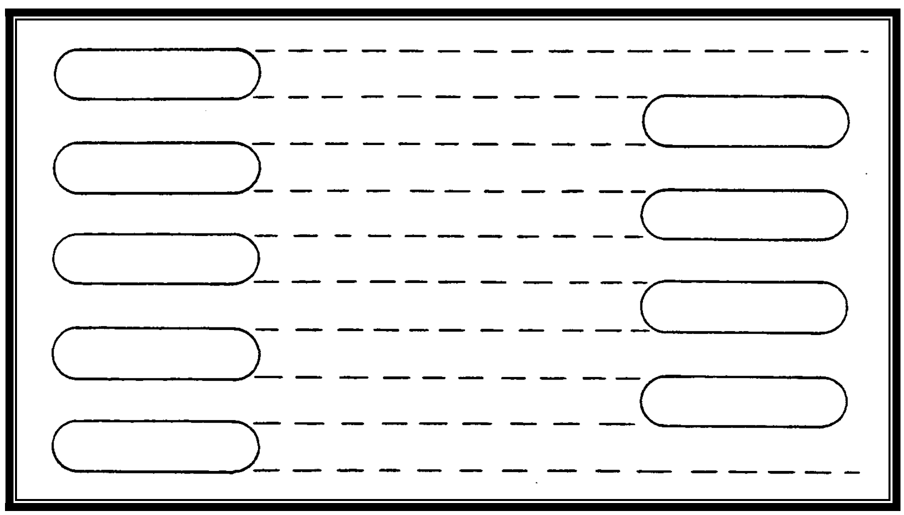

Figure 7-25. Pneumatic Tire Alignment

The Contractor is required to furnish charts and tabulations indicating the contact areas and pressures for the full range of tire inflation pressures and for the full range of tire loadings for each type and size of pneumatic tire roller to be used.

Vibratory Roller

A vibratory roller (Figure 7-26) is a steel-wheeled roller that has the capability of vibrating one or both of the steel rollers. Eccentric weights within the drums rotate at high speeds causing the drum to vibrate and move vertically. This vibration results in vertical impact forces from the drum to the HMA.

Figure 7-26. Vibratory Roller

Only vibratory rollers specifically designed for the compaction of HMA may be used. Vibratory rollers are required by Section **409.03(d)4** to be equipped with a variable amplitude system, a speed control device, and have a minimum vibration frequency of 2000 vibrations per minute. A reed tachometer is required to be provided by the Contractor for use in verifying the operation frequency.

Oscillatory Roller

An oscillatory roller (Figure 7-27) has dual, opposed, eccentric weights that rotate in the same direction around the drum axis. The rotation of the weights causes the drum to move in a rocking motion instead of a vertical motion that is provided by vibratory rollers. This rocking motion creates horizontal and downward sheer forces. Because the drum does not bounce like a vibratory roller, the oscillatory roller provides a smoother surface of the mixture.

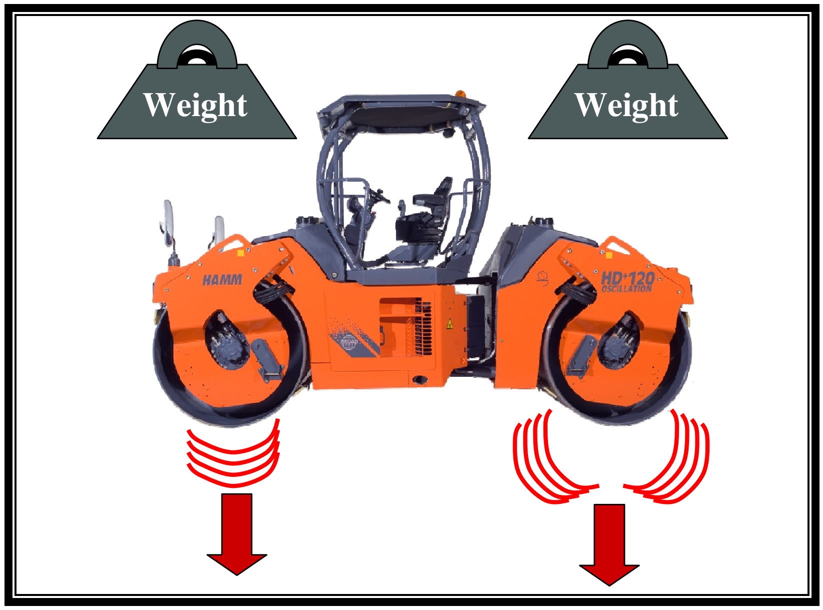

Figure 7-27. Oscillatory Roller

Trench Roller

When the width of a trench is too narrow to accommodate a standard roller, a trench roller (Figure 7-28) is used for compaction. The trench roller is required by Section **409.03(d)6** to be of sufficient weight to exert a pressure of 300 pounds per linear inch of width for the compression wheel. The compression wheel may be either hollow or solid. Weight is added to hollow wheels by filling the wheel with water ballast. Counter-weights are used for rollers with solid wheels.

To provide uniform compaction for the entire width of the compression wheel, the face of the wheel is required to be parallel to the surface being compacted. Trench rollers use a vertical adjustment on the wheel not in the trench to tilt the machine to accomplish this uniform compaction.

Figure 7-28. Trench Roller

Compaction of HMA mixes is conducted with steel wheel, pneumatic tired, vibratory, or oscillatory rollers in three phases:

1) Breakdown or initial rolling

2) Intermediate rolling

3) Finish rolling

Both vibratory and tamper-type paver screeds begin the compaction of the mix as the material flows under the screed. Breakdown rolling compacts the material beyond that imparted by the paver, intermediate rolling compacts and seals the surface, and finish rolling removes the roller marks and other blemishes left from the previous rolling.

Breakdown Rolling

When a single lane is being placed, the outside edge (the low side) of the lane is rolled first. When placing a new mat adjacent to the existing lay, the longitudinal joint is rolled first followed by the breakdown rolling on the low edge.

In general, the roller proceeds straight into the un-compacted mix and returns in the same path, however, when the roller stops and reverses direction the roller should be at an angle to the pavement. The turning movement is normally completed on previously compacted material. The drive wheel of the roller is toward the paver because there is less tendency for the mix to shove under the drive wheel. The recommended pattern for breakdown rolling is illustrated in Figure 7-29.

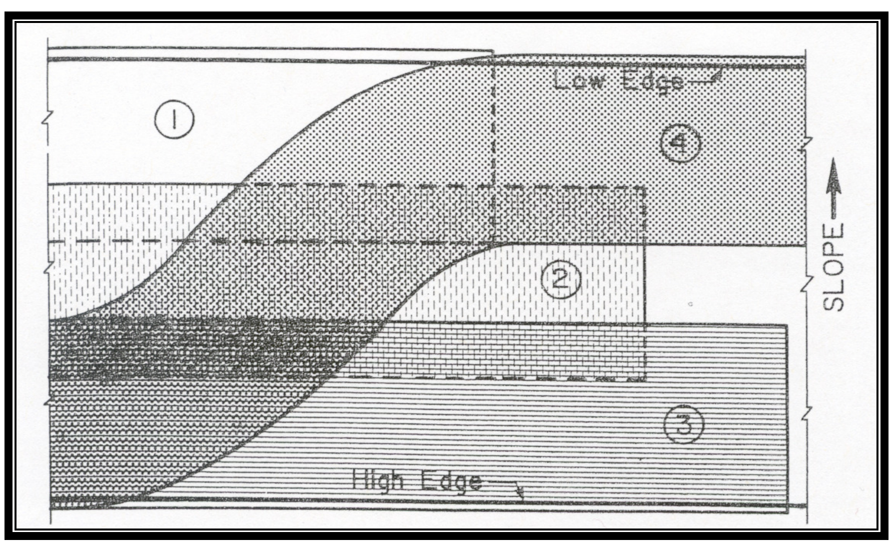

Figure 7-29. Breakdown Rolling Pattern

After the required passes for the breakdown rolling are completed, the roller is moved to the outside of the lane on the cooled portion of the mat to repeat the process on the next segment.

Intermediate Rolling

Intermediate rolling is conducted immediately after the breakdown rolling while the mix is still hot and at a temperature that results in maximum density. The rolling pattern is the same pattern as done for the breakdown rolling.

Keeping the tires hot helps prevent the newly laid material from sticking to the tires for the pneumatic-tired roller. Intermediate rolling is continuous until compaction is attained. If the mixture is accepted in accordance with Section **402**, the rolling pattern is established by the specifications.

Final Rolling

Final rolling is conducted to improve the surface texture. This rolling is completed while the mat is still warm enough so roller marks from the breakdown and intermediate compaction are removed.

SPECIFIED ROLLERS

Compaction may be controlled by the number of passes of a specified series of rollers (Section **402**) or by density (Section **401** and **410**). The QCP for the contract is required to specify the type of rollers to be used. Sufficient rollers are required to be operated to complete the compaction before the temperature of the mix has cooled to a point where the density cannot be obtained.

The rolling operation is required to obtain a fully compacted mat. If the necessary compaction is not attained, subsequent traffic may consolidate the mat further resulting in wheel ruts. Some mixtures, designated as “tender mixtures”, may have a temperature range whereby after the initial breakdown passes, rolling is required to cease until the temperature drops to an acceptable level. Otherwise, the mat may be damaged and/or any density attained by initial breakdown may be lost. Monitoring compaction during the first day of paving is critical to obtain the necessary density.

Section **402.15** for non-QC/QA mixtures allows the Contractor to designate the type of rollers used. Option No. 1 requires a three wheel roller, followed by a pneumatic tire roller and a tandem roller. Options 2, 3, 4, and 5 include different roller and roller application combinations. A roller pass is defined as one pass of the roller over the entire mat. The various options for rolling are included in the following table.

Number of Roller Applications							
Rollers	**Courses ≤ 440 lb/yd^2**					**Courses > 440 lb/yd^2**	
	Option 1	**Option 2**	**Option 3**	**Option 4**	**Option 5**	**Option 1**	**Option 2**
Three Wheel	2		4			4	
Pneumatic Tire	2	4				4	
Tandem	2	2	2			4	
Vibratory				6			8
Oscillatory					6	--	--

PLANT PRODUCTION - NUMBER OF ROLLERS

Before the contract begins, verification that there are a sufficient number of rollers and haul trucks to keep pace with the anticipated plant production is necessary. This procedure is documented in the Quality Control Plan required for the project.

COMPACTION CONTROLLED BY DENSITY

For all QC/QA **(401)** and SMA **(410)** mixtures, density is determined by cores obtained from the mat after all rolling is complete except for the following locations:

1. The total planned lay rate to be placed over a shoulder existing prior to the contract is less than 385 lb/yd^2

2. The first lift of material placed at less than 385 lb/yd^2 over a shoulder existing prior to the contract award

If cold weather paving is allowed, the density is also determined by cores (Section **402.16**).

Quality control procedures for density control are to be included in the QCP in accordance with ITM 803. Non-destructive density testing is required except for cores taken to correlate the density gauge and quality control cores defined in the QCP. Nuclear or non-nuclear gauges may be used. Each gauge is calibrated in accordance with the manufacturer's recommendations and correlated to the type of mixture being placed, depth of mixture, and possibly the underlying base materials. Near the beginning of the paving operation, an area may be designated for testing to determine the proper rolling patterns to achieve the target density. This area is commonly referred to as a "test strip". Non-destructive tests are taken and cores obtained at the same locations in the test strip. The difference between the gauge readings and the measured core densities is determined and used for an "offset" for the gauge.

For Non-QC/QA mixtures, the density is controlled by the specified rolling option (Section **402.15**).

WIDENING

HMA mixtures placed as widening and other depressed areas may be rolled with a trench roller.

ROLLING PATTERNS

Rolling of HMA mixtures may vary depending on the conditions on the project. In general, the best practice for the sequence of the rolling operations is the following:

1) Transverse joints

2) Begin the initial or breakdown rolling at the low side and proceed to the high side of the mat

3) Longitudinal joints – if the new mat is adjoining a previously placed lane

4) Intermediate rolling

5) Finish rolling

Any area that cannot be compacted by rollers is required to be compacted with hand tampers, plate vibrators, or other approved equipment.

Rollers, regardless of the type, are not allowed to be parked on the fresh mat.

Transverse Joints

The ramp section and paper from the day joint are required to be removed prior to starting paving. The screed is set enough higher than the previously laid mat to allow for compaction. When the paver has moved away from the joint, any mix on the surface of the old mat is butted into the joint with a lute. The joint is first rolled transversely with the roller compacting on the old mat and extending into the uncompacted mix about 6 in. Pinching the material into the joint in this way helps attain a tight joint. Planks perpendicular to the lay are used to support the roller to prevent breaking down the edge of the mat while rolling in the transverse direction. Rolling is continued transversely until about 3 ft of the new lay has been rolled.

The roller is then turned parallel to the laydown and rolling is continued. The joint is required to be checked with a straightedge. The roller usually smooths out a bump while the mix is still warm by rolling transversely. Additional material may be required if the straightedge indicates a dip. Material may be added by hand, leveled with a lute, and then re-rolled to correct a dip. However, adding material tends to produce poorer quality surface texture.

Longitudinal Joints

Section **402** requires that the longitudinal joint be compacted in accordance with the following:

1) For confined edges, the first pass adjacent to the confined edge, the compaction equipment shall be entirely on the hot mat 6 in. from the confined edge

2) For unconfined edges, the compaction equipment shall extend 6 in. beyond the edge of the hot mat

Another technique for the construction and compaction of the longitudinal joint that may be used for mixtures placed in accordance with Sections **401** and **410** is illustrated in Figure 7-29 and explained as follows:

1) The uncompacted HMA abutting a cold mat is placed 1/4 in. per 110 lb/yd^2 higher than the cold mat. Any HMA placed on top of the cold mat is required to be removed from the cold mat prior to compaction.

2) The first pass of the breakdown roller to the paver and the return pass from the paver are required to overlap an unconfined edge or cold mat by 6 in.

3) The entire width of the mat is required to receive a uniform number of passes of the compaction equipment. If the mat is tender with pushing and shoving during the compaction operation, the rolling operation is required to be delayed until the mat becomes stable under the roller.

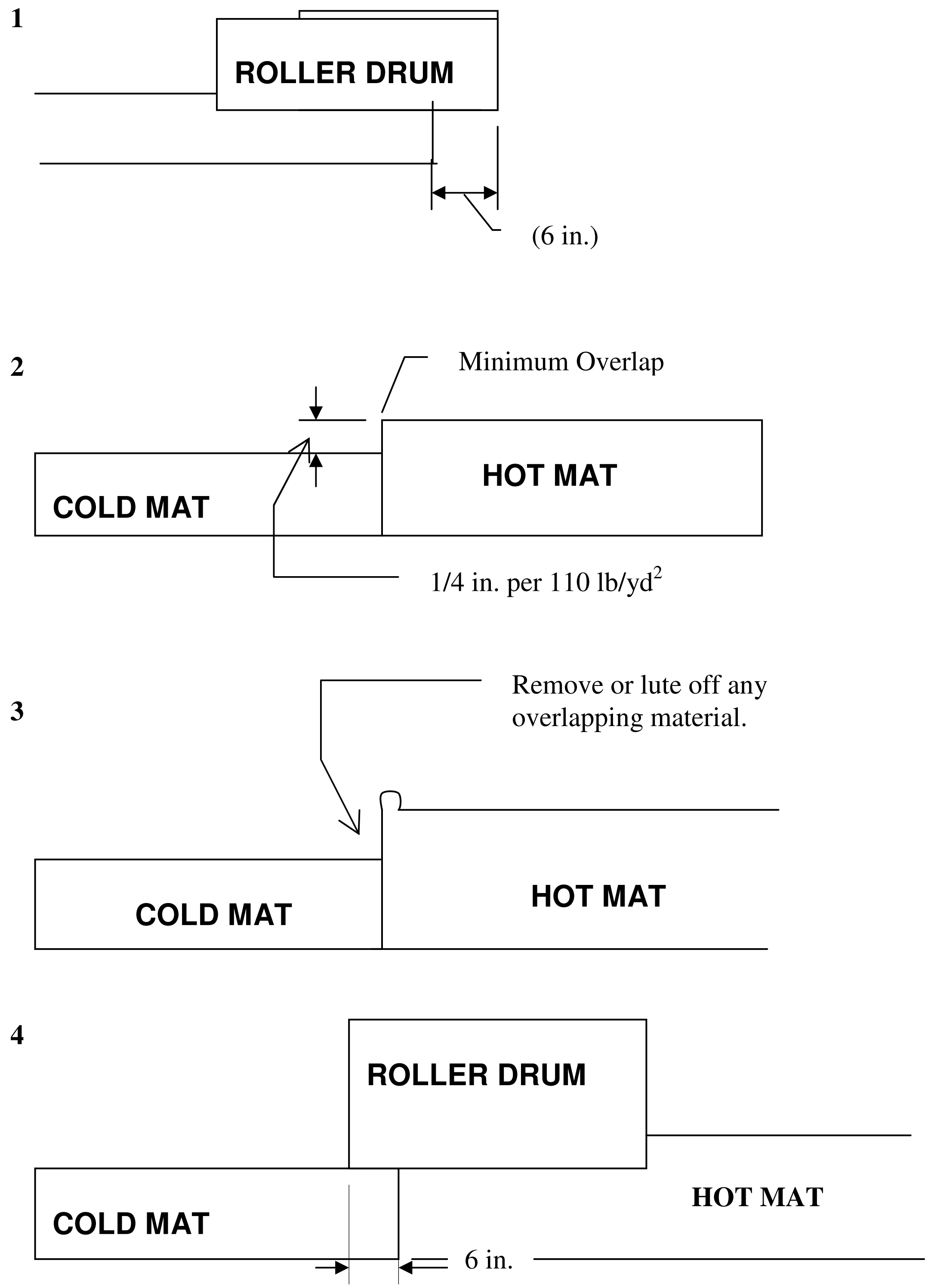

Figure 7-29. Longitudinal Joint Compaction

The notched wedge longitudinal construction joints (Figure 7-30) is another procedure used for constructing the longitudinal joint. This type of joint has shown the potential of improving the construction of longitudinal joints by providing better compaction at the joint.

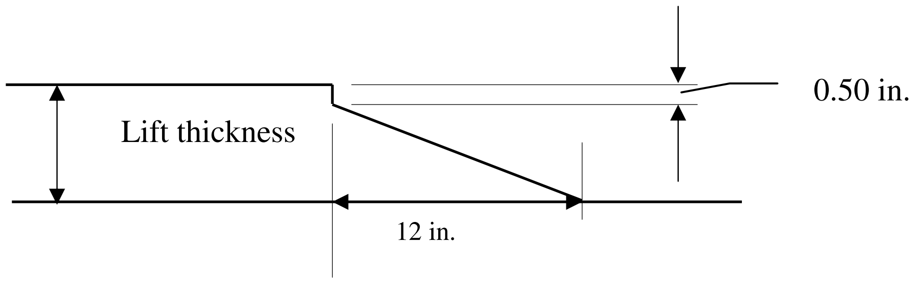

Figure 7-30. Notched Wedge Longitudinal Construction Joint

Joint adhesive materials are also being used for the purpose of sealing construction joints formed between adjacent HMA pavement courses (Figure 7-31). The joint adhesive is applied to longitudinal joints constructed in the top course of dense graded intermediate mixtures and all surface mixture courses. This includes joints within the traveled way as well joints between the traveled way and an auxiliary lane, joints between the traveled way and a paved shoulder, and joints between an auxiliary lane and a paved shoulder.

Figure 7-31. Joint Adhesive Material

ROLLER OPERATOR RESPONSIBILITIES

Breakdown and Intermediate Roller Responsibilities

The breakdown and intermediate roller operator responsibilities for vibratory rollers include obtaining pavement density while the HMA is in the proper temperature range for compaction without risking aggregate damage. Rolling with the vibration toward the paver and establishing the rolling pattern with the fewest side-by-side passes as possible is required. Also, controlling the roller speed to provide proper drum impact, keeping up with the paver, and operating in the best temperature zone are additional responsibilities. If one roller cannot maintain the production rate, a second breakdown roller will be needed. Specific responsibilities include:

1) Communicating with the paving crew and foreman for the project requirements prior to arrival of the HMA

2) Doing daily maintenance on the roller and checking the water system

3) Determining the lift thickness

4) Being aware of the material temperature at delivery to the paver and behind the screed

5) Determining if the rolling drum mode is vibratory or static depending on the requirements to achieve density

6) Making the required amplitude adjustments for both drums for the mix design, material thickness, and the temperature zone

7) Optimizing the water system controls to avoid material pick-up and eliminate excessive water usage

8) Establishing the proper rolling pattern considering the paving width, roller drum width, unsupported edges, and drum overlap

9) Determining rolling speed to achieve the proper impact spacing and smoothness requirements

10) Monitoring rolling temperature and working with the optimum temperature zones

11) Recognizing tender mixtures and adjusting the roller pattern

12) Making the required rolling coverage to achieve density requirements

13) Adjusting rolling operations to satisfy the density, smoothness, and production rates

14) Maintaining consistency throughout the entire working shift

Finish Roller Responsibilities

The finish roller operator responsibilities include removing all surface marks and blemishes from the finished pavement. The operator may be required to achieve final compaction in some cases where breakdown and intermediate rolling have not achieved the target density. Rolling at the necessary speed to maintain production is required and using vibration is rarely done. Specific responsibilities include:

1) Communicating with the paving crew, foreman and breakdown operator for the project requirements

2) Confirming maintenance and water system checks on a daily basis

3) Being aware of the material temperature and avoiding the tender zone

4) Determining if the rolling mode is vibratory or static depending on the requirements to achieve density and smoothness

5) Optimizing the water system controls to avoid pick-up and eliminate excessive water usage

6) Establishing the proper rolling pattern determined by the paving width, rolling drum width, unsupported edges, and drum overlap

7) Coordinating the final rolling process with QC personnel

8) Monitoring the rolling temperature and working within the optimum temperature zones

9) Making the required rolling coverage to achieve density requirements and to remove drum edge marks

10) Maintaining consistency throughout the entire working shift